Appendix H: Air Resource Monitoring Issues in the Klamath Network.

1.1. Background

Air quality is a critical component of the NPS mission "to conserve the scenery and the natural and historic objects therein…by such means as will leave them unimpaired for the enjoyment of future generations." Air resources are not specifically mentioned in the mission; however, air pollutants can impact visibility, visitor enjoyment, human health, and natural and cultural resources. These air quality related values (AQRVs) often include the unique resources that the parks were designed to protect.

Many visitors come to the national parks to enjoy the spectacular vistas, clean air, and clear night skies that they do not find in the urban areas where they may reside. Low visibility and the human health impacts associated with poor air quality affect visitor enjoyment and satisfaction with their experience which can, in turn, affect the economics of the surrounding communities and the future support for the park itself.

In addition to impacts on visitor experience, air quality can have significant impacts on the natural, cultural, and human resources in the parks. Pollutants of greatest concern for the NPS, in general, are ozone, sulfur and nitrogen compounds, and particulate matter. Ozone can cause injury to vegetation and can impact the health of visitors and park employees. Sulfur and nitrogen are the principal constituents of acidic deposition, which can significantly impact aquatic and terrestrial ecosystems as well as cultural resources. Particulate matter is a human health concern and, in the form of sulfates and carbon particles, is very efficient at scattering light, resulting in visibility impairment (Eilers et al. 1994).

With the Clean Air Act, Congress established increased protections for 48 national park units designated as Class I areas along with additional measures to protect the remaining park units – Class II areas. The Klamath Network (KLMN) includes four Class I areas (Crater Lake NP (CRLA), Lassen Volcanic NP (LAVO), Lava Beds NM (LABE), and Redwood NP (REDW)) and two Class II areas (Oregon Caves NM (ORCA) and Whiskeytown NRA (WHIS)). The majority of NPS air resources monitoring occurs in the Class I parks, while the Class II parks often obtain air quality data from cooperating agencies.

1.2. Air Quality Related Values

AQRVs are resources, identified by federal land managers, which may be adversely affected by an increase in air pollution. These values include visibility and the scenic, cultural, biological, and recreation resources of an area. AQRVs of interest to the Inventory and Monitoring program and potential impacts to those values are listed below.

Water Quality
Nitrogen and sulfur compound deposition can affect freshwater lakes, streams, ponds, and estuarine ecosystems. Both nitrogen and sulfur emissions can form acidic compounds (e.g., nitric or sulfuric acid) that can cause acidification of waters when deposited into ecosystems with low buffering capacity. These changes in water chemistry affect algae, fish, submerged vegetation, and amphibian and aquatic invertebrate communities. Nitrogen deposition can also lead to eutrophication, with symptoms such as fish kills, toxic algal blooms, and loss of species diversity in coastal and estuarine ecosystems.

Aquatic Biota
Aquatic biota can be affected at the community (reduced species richness), population (increased mortality), and organism (reduced growth) level by water body acidification from atmospheric deposition (NPS 2000). As pH levels decline in streams and lakes, negative impacts can occur in all levels of aquatic biota. In addition to contributing to acidification, nitrogen can enrich aquatic ecosystems, favoring certain algal species.

Amphibians
Amphibians are potentially susceptible to various air pollution impacts due to their biphasic life-style. Environmental contaminants and increased UV-radiation, due to reductions in upper atmospheric ozone, have been investigated as contributing factors to recent amphibian declines (USGS 2004). Amphibian eggs lack protective shells and are often laid in shallow water, which makes them particularly susceptible to contaminants in the water and damage from UV-radiation.

Soils
Deposition of sulfur and nitrogen compounds can lead to soil acidification. Nitrogen compounds can also have a fertilization effect on soils. In some areas of the country, elevated nitrogen deposition has altered soil nutrient cycling and vegetation species composition. These impacts can, over time, affect species higher in the food chain.

Appendix H. Air Resource Monitoring Issues in the Klamath Network (continued).

Plant Species

Vascular: Vascular plants can be affected by increases in ozone, sulfur dioxide, and nitrogen deposition. Ozone sensitive plant species can show visible foliar injury, reduction in growth and productivity, and increased sensitivity to stress with increased levels of pollutant exposure (Porter 2003). Long-term exposures can result in shifts in species composition, with ozone tolerant species replacing intolerant species. In addition to a predisposition for ozone sensitivity in the plant itself, certain environmental variables such as soil moisture, presence of other air pollutants, insects or diseases, and other environmental stresses affect a plant's response to exposure. The Environmental Protection Agency (EPA) has established an ozone standard to protect human health; however, there is no standard to protect vegetation and there is much evidence to suggest that the human health-based standard is not protective of sensitive vegetation. Nitrogen deposition into terrestrial ecosystems can cause changes in plant species composition and abundance, affecting biodiversity. Certain species, often invasives, are better able to utilize excess nitrogen over native species, eventually replacing them.

Ozone Assessment: Two metrics used to describe vegetation exposure to ozone, the Sum06 and the W126, are believed to be biologically relevant, as they take into account both peak ozone concentrations and cumulative exposure to ozone. Thresholds have been developed for both metrics to assess potential risk to vegetation.

SUM06 threshold values for vegetation injury:

Natural Ecosystems	8 - 12 ppm-hr	(foliar injury)
Tree Seedlings	10 - 16 ppm-hr	(1-2% reduction in growth)

W126 thresholds for injury to ozone sensitive vegetation:

Highly Sensitive Species	5.9 ppm-hr
Moderately Sensitive Species	23.8 ppm-hr
Low Sensitivity	66.6 ppm-hr

The effects of atmospheric deposition on vascular plants are often less obvious than ozone-induced injury. Over time, excess nitrogen deposition may cause plants that have adapted to nitrogen-poor conditions to be out-competed and replaced by nitrogen-loving non-native species. In addition to changes in species composition, there may be increases in productivity, resulting in increased biomass (i.e., fuel loading) and fire frequency.

Nonvascular: Sulfur dioxide (SO_2) does the most widespread damage to nonvascular plants. Lichens and many mosses lack protective surfaces that can selectively block out elements including pollutants that are dissolved in rainwater; since lichens and mosses lack roots, surface absorption of rainfall is their only means of obtaining nutrients. Lichens have been used worldwide as air pollution monitors because relatively low levels of sulfur, nitrogen, and fluorine-containing pollutants adversely affect many species by altering community composition, growth rates, reproduction, physiology, and morphological appearance. Lichens are also used as pollution "biomonitors" because they concentrate a variety of pollutants in their tissues and can provide good baseline information. Lichens are long-lived and can have extensive geographical ranges, allowing study of pollution gradients over time for large areas.

Visibility
At non-urban monitoring sites across the NPS, sulfate and carbon particulates are the greatest contributors to reduced visibility. The NPS conducted an intensive field monitoring program in the Pacific Northwest during the summer of 1990, which showed that sulfates account for over 40% of visibility reduction, while carbon (organics and light absorbing carbon) is responsible for about 20% and nitrates and coarse mass for 10%. Service-wide visibility monitoring shows that seasonal differences in visibility conditions exist in national parks. For most areas of the country, visibility tends to be best during the winter and worst during the summer—the peak visitation season.

Human Health
The EPA has documented the human health effects associated with acute and chronic exposures to air pollutants, including ozone and fine particulates. Because of these health effects and concern for the health and safety of its visitors and employees, the NPS has developed an advisory system in several parks where levels are likely to approach or exceed the EPA standards (8-hr average ozone ≥80 ppb or 24-hr average fine particulates ≥65 ug/m^3) (EPA 2004). Health effects associated with exposures to ozone include acute respiratory problems, aggravation of asthma, temporary decreases in lung capacity, inflammation of lung tissue, and impaired immune system defenses. Fine particulate matter can cause respiratory (aggravation of asthma and bronchitis) or cardiovascular (irregular heartbeat and heart attacks) problems.

1.3. Air Quality and Air Quality Related Values in the Klamath Network Parks

Most of the KLMN park units are distant from major cities and pollution sources but can still experience poor air quality from pollutants such as ozone, nitrogen oxides, sulfur dioxide, volatile organic compounds, particulate matter, and toxics. These air pollutants affect, or have the potential to affect, Network air quality and natural resources.

The four Class I parks in the Klamath Network all have at least one type of air quality monitoring within the park boundaries, but the two Class II parks have no within-park air quality monitoring stations (Figure 1). LAVO has the most extensive air quality monitoring program in the Network and is also the only park with documented impacts to AQRV. The history of monitoring at each park unit can be found on the NPS Air Resources webpage: http://www2.nature.nps.gov/air/Monitoring/MonHist/index.cfm. For park units without on-site monitoring, estimates of many air quality parameters can be found in the Air Atlas (Sutton and Ray 2005) at http://www2.nature.nps.gov/air/Maps/AirAtlas/index.htm. Table 1 summarizes a select group of air quality parameters for the Klamath Network.

Appendix H. Air Resource Monitoring Issues in the Klamath Network (continued).

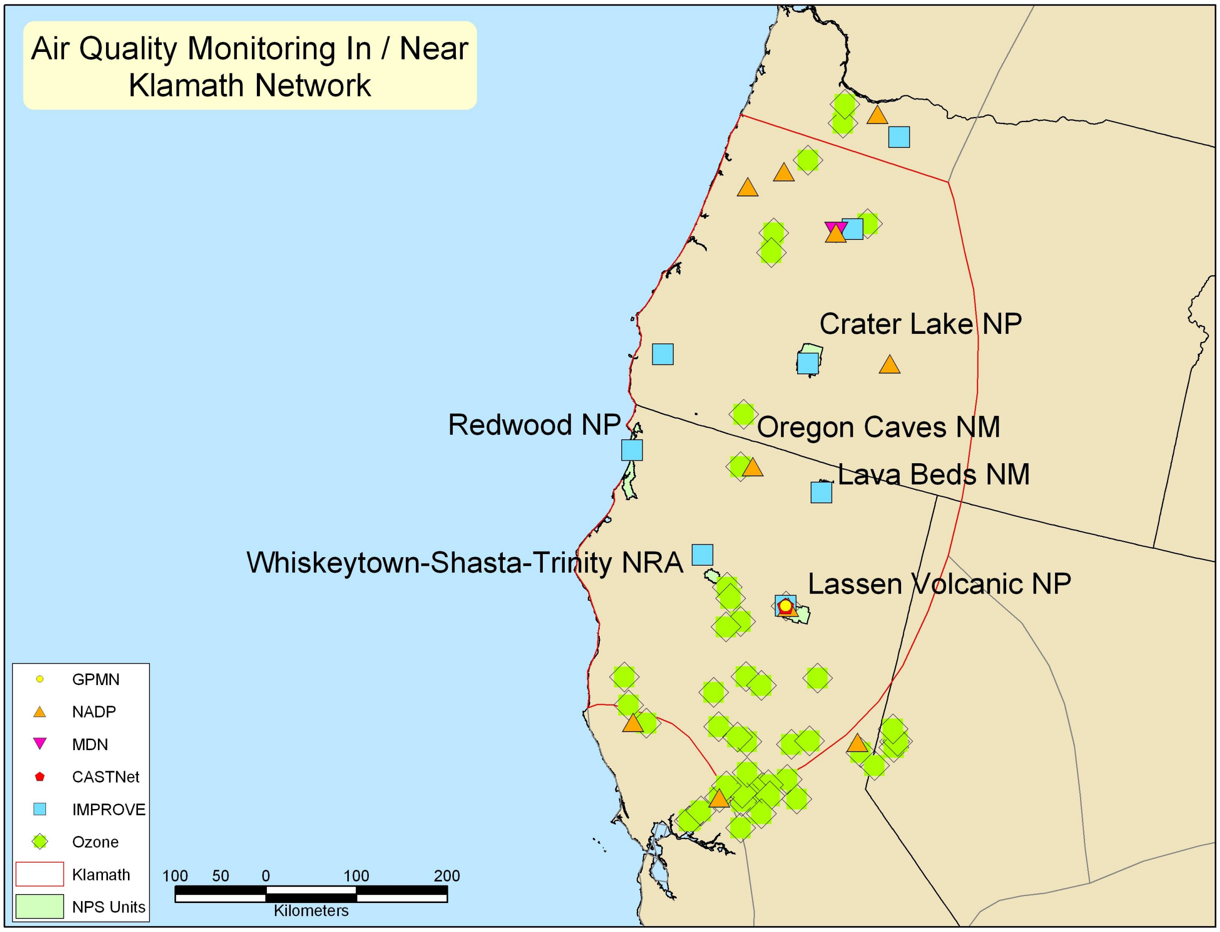

Figure 1. Air quality monitoring in and near the Klamath Network. GPMN= NPS Gaseous Pollutant Monitoring Network for ozone; NADP= National Atmospheric Deposition Program; MDN= Mercury Deposition Network; CASTNet= Clean Air Status and Trends Network; IMPROVE=Interagency Monitoring of Protected Visual Environments; Ozone=ozone monitoring by states.

Appendix H. Air Resource Monitoring Issues in the Klamath Network (continued).

Table 1. Estimates of selected air quality parameters for KLMN parks (from Air Atlas).

		OZONE ------	------	------	------	------	------	NADP kg/ha/yr	---------	VISIBILITY IMPROVE	------
Park Code	AQ Class	2^{nd} Hi 1hr	4^{th} Hi 8hr	#8 hr >85	# 1hr >100	Sum06 3 Mo Avg	W126 Season	Wet S	Wet N	bext_Clear	bext_Hazy
CRLA	I	96.5	71.0	4.0	6.4	9.2	14.0	0.48	0.52	5	30
LAVO	I	101.5	78.8	5.0	9.3	19.2	35.0	0.45	0.74	5	37
LABE	I	96.7	75.3	4.4	7.8	17.1	27.4	0.48	0.62	6	39
ORCA	II	93.5	71.1	3.7	6.2	12.3	16.9	0.50	0.55	7	46
REDW	I	93.9	72.0	3.7	7.4	19.4	20.0	0.55	0.67	8	52
WHIS	II	100.8	78.1	5.8	13.1	35.3	30.7	0.51	0.75	6	42

Class: refers to an area's designation under the Clean Air Act
Ozone information represents 5-yr average of annual values from 1995-1999
2^{nd} High 1 hr concentration (ppb): indicates peak values for ozone; old standard of 0.12 ppm (120 ppb) based on 2^{nd} hi, 1-hr average
4^{th} High 8 hr concentration (ppb): new ozone standard of 0.08 ppm (80 ppb) is based on 4^{th} hi, 8-hr average
8 hours > 85 ppb: indicates how often the area would exceed the new 8-hr standard of 0.08 ppb
1 hours > 100 ppb: high peaks in ozone concentration, as well as cumulative dose, contribute to vegetation injury
W126 (ppm-hrs): Cumulative exposure index that assigns greater importance to higher ozone concentrations
SUM06_3mon (ppm-hrs): sum of hourly ozone conc. ≥ 0.06 ppm (60 ppb) over 6 months (~growing season, i.e., cumulative dose)
NADP information represents 6-yr average of annual values from 1995-2000.
NADP deposition (kg/ha/yr): estimate of pollutants deposited to ecosystem by precipitation
NADP Total S – sulfur from sulfate deposited by precipitation
NADP Total N – inorganic nitrogen (ammonium plus nitrate) deposited by precipitation
Visibility IMPROVE information represents 5-yr average of annual values from 1995-1999
bextClear – measure of light scattering and absorption, i.e., extinction, by particles in the air on an average clear day
bextHazy – measure of light scattering and absorption, i.e., extinction, by particles in the air on an average hazy day

Two KLMN parks (WHIS and LAVO) are in counties (Shasta and Tehama (California)) that are listed as non-attainment for state ozone standards (California Air Resources Board 2004). All counties in the KLMN are in attainment of the most recent federal 8-hr ozone standards. Attainment status indicates that ozone concentrations in the parks are not harmful to visitors and staff; however, some sensitive plant species are affected at ozone levels present in the Network parks.

The NPS conducted an ozone risk assessment for KLMN parks, based on the concept that plant foliar ozone injury is the result of the interaction of the plant, ambient ozone, and the environment. Completed in 2004, the final assessment can be found on the NPS Air Resources page: http://www2.nature.nps.gov/air/Pubs/pdf/03Risk/klmnO3RiskOct04.pdf. This risk assessment will be useful in deciding whether to conduct future ozone monitoring or foliar injury assessments. Ozone concentrations and cumulative exposures may be sufficient to induce ozone injury under certain conditions at several of the units in the Klamath Network. The final risk assessment for the Klamath Network indicates that the risk for ozone injury is high at WHIS; moderate at CRLA, LABE, ORCA, and REDW; and low at LAVO.

Atmospheric deposition in the KLMN is generally low compared to other parks, especially those in the East and Midwest. In order to assess ecosystem impacts from atmospheric deposition, it is desirable to have estimates of total deposition, that is, wet plus dry deposition. LAVO is the only KLMN park with on-site monitoring of both wet and dry deposition. Table 1 shows estimates of wet deposition for all six parks. Even though these estimates indicate that deposition of both nitrogen and sulfur are elevated above natural levels of deposition (approximately 0.25 kg/ha/yr in the western US), ecosystems in the Network are generally well-buffered with sufficient base cations in soils and waters to neutralize these acids.

In the most recent Service-wide air quality report, the NPS Air Resources Division (2005) presented data on air quality trends from 1995-2004 in Class I NPS units. In this report, visibility trends at CRLA, LAVO, and REDW showed significant improvement (at the 0.05 level) on the clearest days, while on the haziest days, CRLA and LAVO were stable (no trend) and REDW showed improvement (at the 0.15 level).

Park Specific Issues

Crater Lake NP: CRLA is located in an area of southeastern Oregon that has few emission sources, and it has a low risk of air pollution impacts to its AQRVs. The most sensitive receptor in the park is Crater Lake itself. Acidification of the lake is not a concern due to its natural buffering capacity, but an increase in nitrogen loading could cause lake productivity to rise resulting in lower transparency (Eilers et al. 1994).

Lassen Volcanic NP: LAVO receives emissions from the Sacramento Valley Air Basin as well as potential deposition from trans-Pacific sources. The park's main AQRVs of concern are ozone injury to vegetation, acidification of aquatic ecosystems, and visibility degradation. Monitoring activities have revealed foliar symptoms of ozone injury to both Ponderosa and Jeffrey pine, and recent trends show that ozone levels are increasing in the park. A recent air quality report by the NPS (2002) showed significant degradation (at the 0.15 level) in LAVO for two measures of ozone (average daily 1-hr maximum and annual 4^{th} highest 8-hr average) from 1990-1999. Estimates of sulfur and nitrogen wet deposition in the park are well below the minimum levels generally associated with resource impacts; however, the high elevation lakes of LAVO may be more sensitive to acidification than any other aquatic resources in the western parks (Sullivan et al. 2001). Recent research, particularly on nitrogen, indicates that even very low levels of nitrogen may affect ecosystem structure and function. Visibility is frequently impaired in LAVO, especially during the summer, largely due to organics and sulfates.

Lava Beds NM: LABE is located within California's Northeast Plateau Air Basin, which has low population density and relatively low air emissions. Visibility is the most sensitive AQRV in the park. Visibility at LABE is generally greater than in other parts of the country, but increasing haze is a concern in the park. There are no other known impacts to AQRVs in the park at this time.

Redwood NP: REDW frequently has impaired visibility due largely to sulfates, nitrates, and organics. Weather, wind, and coastal fog play the greatest role in visibility at the park. Ozone levels are low within the park and there is no reason to suspect any vegetation damage at these levels. The streams in the park may be sensitive to acidification from atmospheric deposition since they are moderately dilute; however, park streams have a moderate buffering capacity and would not be subject to acidification unless the deposition of S or N increased dramatically (Sullivan et al. 2001).

Oregon Caves NM: ORCA is located in rural southwestern Oregon in an area with few emission sources. Baseline air quality data has been collected through lichen tissue chemistry studies (Blett et al. 2003), but no air quality monitoring stations are located in the park. Air Atlas estimates (Table 1) from nearby monitors indicate relatively low levels of pollutants in the park, and there are no known risks to AQRVs at this time.

Whiskeytown NRA: WHIS is located in the upper Sacramento Valley, seven miles from Redding, California (population 85,000). No air quality monitoring studies have been conducted within WHIS; however, Air Atlas estimates (Table 1) from nearby monitors indicate that the park has high levels of ozone, which could impact vegetation in the park. WHIS has ozone concentrations similar to those at LAVO, where foliar vegetation injury has been documented. No information is available on risks to other AQRVs.

1.4. Anticipated Trends and Effects on Park Management

The condition of a park's air resources can have resounding effects on other park values, yet park managers often have little to no regulatory authority over the quality of air entering the parks. Since air quality is regulated on a regional, state, and national scale by various outside agencies, park managers often need to work with these agencies to accomplish their goals. As population levels in cities rise, pollution sources are anticipated to increase and park managers will need to ensure that outside emissions are not significantly impacting AQRVs in the parks. Impacts to ecosystem health and visitor satisfaction may occur at lower pollution levels than those regulated by state and federal law since air pollution laws are designed to protect only human health.

In addition to protecting AQRVs within the parks, managers must ensure that the parks themselves are in compliance with air quality regulations. The four California KLMN parks had baseline air pollution emission inventories for internal park sources completed for the year 1998, and CRLA had an inventory completed for baseline year 2001 (EA Engineering, Science, and Technology, Inc 2000a-d and 2003a and b). According to these studies, prescribed burning was the largest internal emission source in all four parks. For all four, internal emissions sources, including prescribed burning, were minor compared to external emission sources affecting the parks. Protecting human health and air quality while restoring fire dependent ecosystems will continue to be a major challenge for park managers. Approximately 70% of the particulates emitted from biomass burning fall within the National Ambient Air Quality Standards for particulates less than 2.5 microns in diameter ($PM_{2.5}$), and the Regional Haze Regulations require measures to improve visibility in Class I parks, which could include increased controls on prescribed burning.

Appendix H. Air Resource Monitoring Issues in the Klamath Network (continued).

With continued monitoring of air quality trends, both within and outside the parks, resource managers in the KLMN will be able to further assess potential threats and work to minimize the impacts to network AQRVs.

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